Good Audio

Part One
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Do you want to improve the sound of your transmitted audio, but don't quite know how to go about it? Have you heard really fine audio, and you would like to duplicate it? Are your contacts having trouble even understanding what you are saying? Stay tuned, and in this article, I will discuss what makes good audio and how to improve your transmitter. Fundamentals will be mixed in with some good, practical advice.

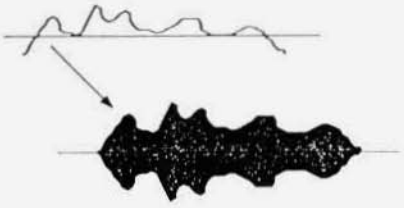

Fig 1

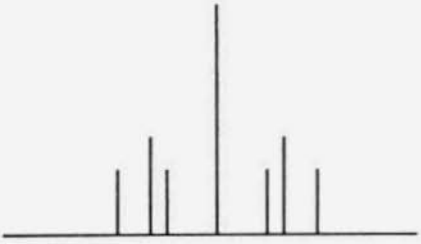

Fig 2

First, let's cover some basics. In AM, the transmitted peak carrier voltage mirrors the voice waveform, varying from zero up to approximately twice the unmodulated carrier voltage. This variation of carrier voltage causes sidebands to be generated, and the bandwidth of the signal is twice the highest modulation

The author at his operating position showing some of his audio processing equipment.

frequency. Figure 1 shows the modulation of a carrier in the time domain, where the horizontal axis represents time, moving left to right, and the vertical axis represents the carrier voltage. The second figure shows the spectral distribution in the frequency domain, where here the horizontal axis represents frequency. The sidebands surround the carrier, and reproduce the spectral distribution of the audio signal. It will help to visualize the signal in either the time or frequency domain to understand why some improvement techniques work, and why some don't. We will return to these two representations often.

Next, let's clear up some misconceptions. Good hamband AM audio is not the same as hi-fi audio. A broadcast-quality transmitter fed with a broadcast-quality mike would sound flabby and undermodulated. The highs would be lost in the narrow bandwidth of the receiver. The low-frequency components would dominate the modulation power, but would be lost to the low-frequency roll-

off in the receiver. What's left of the midrange would sound weak, and the signal would lack punch. Proper response shaping results in audio that sounds powerful, natural and undistorted.

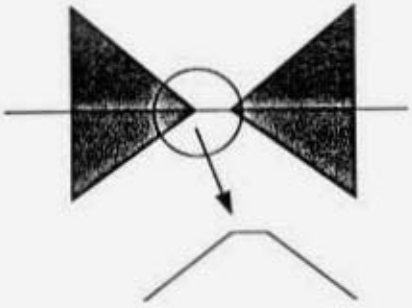

fig 3

Overmodulation is not the only cause of splatter. Figure 3 shows a detail of the carrier amplitude crashing to zero on a negative overmodulation peak. The waveform represented by this severe clipping has a sharp kink (time domain), which requires a wide set of frequencies to represent it (frequency domain). This wide frequency spectrum creates sidebands far away from the carrier, producing splatter and buckshot. Clipping or parasitics in the transmitter can also produce splatter.

Low-level modulation found in single-sideband transmitters operated in the AM mode can be quite acceptable, if adjusted correctly. Many older broadcast transmitters used low-level modulation followed by several stages of linear amplification. When they are correctly tuned, the results can be completely satisfactory. In fact, if a balanced modulator is used, overmodulation will not cause splatter – it will just result in audio distortion if an envelope (diode) detector is used (frequency domain: two sidebands, reduced carrier), but can be demodulated without distortion with a synchronous detector (Staples, ER #30,34). The most common problem with low-level modulation schemes is that the amplifiers following the modulated stage are not operated in their linear range and flat-topping or crossover distortion usually occurs.

I now will discuss each component of the audio chain from the microphone to the receiver, along with some commercial AM broadcasting practice.

Microphones

Your audio really starts with your own voice, which I can't do much about, so we'll begin with the microphone. I have heard wonderful audio from $1.50 Radio Shack electret mikes, and lousy audio from improperly equalized $1000 RCA 44-DX velocity mikes.

It is important to emphasize the middle range of the voice without overdriving with the bass components. Without a roll-off of the bass register below about 200 Hz or so, the lows in the voice will determine the modulation level. The remaining middle register will be weak in comparison and the signal will sound undermodulated and bassy. In addition, many transmitters can't handle the lower frequencies without distortion.

The high frequency response of some microphones may have sharp resonances or holes. A resonance produces a ringing sound frequently heard on older telephone equipment. Missing spectral bands can also sound like ringing. Audio physiologists know that if an audio source is missing spectral segments, the ear-brain system will attempt to fill that section in. This process results in listener fatigue, which can result in a ringing sensation in the ear. (This is a common effect produced by cheap hi-fi's). A sharp cut-off in the audio frequency spectrum will produce the same effect. A smooth roll-off of the lows and the highs with no sharp peaks in the midrange spectrum avoids listener fatigue.

Some microphones, such as ribbon velocity mikes, become bassy when close-talked. These mikes may have a variable low-frequency roll-off selector switch (voice-music1-music2) incorporated in the microphone itself to shape the bass response.

continued next page

The directional characteristics of a microphone may be important. If you prefer to talk far from the mike, you may want to consider a directional mike which will not pick up wall echo. If you close-talk the mike, then any pressure-sensitive microphone should work fine.

Most ham mikes are crystal, dynamic, or electret (a convenient form of capacitor mike). The crystal mike requires a high-impedance load to preserve the low-frequency response. The crystal mike equivalent circuit is a voltage source in series with a few hundred picofarad capacitor. This forms a high-pass filter with the grid resistor of the first amplifier stage. The resistor must be large enough, a few megohms, to preserve the bass response, but not too large, otherwise the grid will float negative, changing the bias of the first stage. Good mike cord shielding is essential, and the cord should be as short as possible.

Some crystal mikes such as the amplified D-104 have a preamp in the stand providing a higher signal level at a low source impedance. However, unless the audio output level is correctly adjusted, the audio amplifier stages in the transmitter before the gain control may be overdriven by the high output. Another potential problem with the amplified D-104 is the presence of a strong voltage transient when the talk bar is pressed or released, which may ride through the modulator and stress the modulation transformer. In higher power transmitters, place a spark gap across the modulation transformer secondary to protect it against transients (Dennison, ER #25). Some transmitters, like the Johnson Ranger, have no d.c. blocking capacitor between the mike connector and the grid of the first audio stage. A leaky electrolytic coupling capacitor at the D-104 amplifier output may upset the first audio stage bias. Include a d.c. blocking capacitor of at least 0.01 microfarad before the grid resistor to prevent any d.c. from the mike from upsetting the bias on the first amplifier stage. Don't replace the electrolytic in the D-104 with a smaller capacitor, as the mike won't then drive low-impedance loads.

The D-104 mike seems to have an almost ideal frequency response and relatively high output, and doesn't need any more response shaping. Its popularity attests to this, with many hams having collected several of them. The crystal cartridge does eventually degrade, however, but is easily replaced at modest expense.

The small electret microphones sound just fine, and their built-in amplifier provides a low-impedance output. They tend to have a fairly flat response, with a bit of bass fall-off, and work fine without equalization. I have not heard enough dynamic mikes on the bands to have an opinion about their suitability for AM work.

Broadcast-type mikes are fun to use on an AM transmitter, but need to be equalized, knocking down the bass response, to render their frequency response more suitable. You must speak a foot or two away from ribbon mikes, but they have directional characteristics that allow you to put echoes or noisy transmitters in the directional nulls.

Mike Mixers

A multi-input mike mixer may be a valuable addition to your station. It allows you to test several microphones in quick succession, and to include other audio sources such as tape recorders.

Mixers come in a wide range of capabilities, from small units with two high-impedance mike inputs to full studio consoles. The more elaborate mixers usually have low-impedance microphone inputs, with separate preamps for each mike. The preamps may be modular plug-in units low-level inputs, which can be removed for high-level inputs. Amplified D-104's can drive the 600-ohm high level inputs nicely.

These mixers frequently support monitoring functions, such as a VU meter, or a headphone output. The mixer output level is fairly high, which is not suitable for

feeding into the transmitter mike input, but is well adapted to feed other audio processing equipment. The mixers usually have no provision for push-to-talk circuits. New connectors and push-to-talk wiring may be added to the mixer. Below, I will discuss how to feed high-level signals into amateur transmitters.

Phasing

The human voice has an asymmetric waveform, and to increase the average modulation percentage, it helps to establish the phase of the audio chain so that the higher polarity peaks in the acoustical waveform produce upward modulation of over 100% while maintaining the peak negative modulation level below 100%. Commercial AM broadcasters use equipment which constantly monitors the symmetry of the audio feed to the transmitter and automatically switches the phase to favor the positive modulation peaks, which are allowed to reach 125%.

One way to estabiish the phase of the audio is to observe the modulated signal on an oscilloscope and observe whether the upward peaks exceed the downward. If they don't, invert the phase somewhere in the system.

The phase can be conveniently inverted at two points: the microphone and the modulation transformer secondary. The wires to the microphone element can usually be interchanged, as long as neither side of the element itself is ungrounded, such as in the D-104. The secondary leads of the modulation transformer can also be interchanged. If negative feedback from the modulation transformer is not used (the Viking Ranger is an exception), primary leads can also be interchanged, usually by switching the plate caps.

If equalizers, limiters or other audio processors are in the audio chain, they should maintain the phase when switched in or out. These units usually have balanced 600-ohm inputs and outputs, and reversing the leads inverts the phase.

Equalizers

Equalizers might improve your audio quality. A good amplified D-104 with a modified Valiant transmitter (Staples, ER #24) doesn't need any equalization at all. An equalizer won't help a rotten mike, with lots of sharp peaks in its response. Bassy or tinny audio without high-frequency resonances may be helped by an equalizer. The sort of equalizer you might try is the 10-band octave-type used in hi-fi systems and available at electronics flea markets. The 10-band variety usually allows each octave to be boosted or attenuated by about 10 or 15 dB. Connecting the two stereo channels in tandem will achieve up to a 30 db boost or cut.

One way to tune an equalizer is to rely on a listener using his normal station receiver to talk you into the best response adjustments. By including the receiver in the loop, the receiver audio response is taken into account.

If the transmitter has distortion at the extreme ends of the spectrum, cut them off. Many transmitters cannot modulate below 200 Hz without considerable distortion. There is no point in extending the audio range above 8 kHz.

Articulation tests show that if frequencies below 570 Hz are eliminated from speech, 96% of random syllables can be interpreted correctly, and 90% with frequencies below 960 Hz eliminated. The corresponding high frequency cutoffs for the same syllabic identification accuracy are 5000 and 3100 Hz (Radiotron Designer's Handbook, and Kleronomos, ER #11). It is clear than a limited frequency range does not affect accurate understanding, but it does affect the naturalness of the sound. For heavy QRM situations, you may want to emphasize only the middle of the spectrum with your equalizer settings.

The audio response of various transmitters varies widely. The Collins 32V series has a rather narrow response, and the Johnson Ranger is somewhat wider. The modified Valiant is excellent, (+ dB from 70 Hz to 15 kHz), with low distortion. An equalizer can correct some of the

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deficiencies of a transmitter with limited frequency range, and problems with bassy microphones. Transmitter problems such as narrow bandwidth or distortion are better dealt with by modifying the transmitter itself, as forcing preemphasized audio through an inadequate transmitter can make matters worse. Correct the response problems in the transmitter first, and then consider adding an equalizer if you think it's still needed.

A word of caution on frequency response testing of the transmitter itself. Don't sine-wave modulate the transmitter at high level when measuring its frequency response: keep the modulation level low. Most ham transmitters are not built to endure 100% sine-wave modulation, which stresses the modulator tubes, transformer and power supply.

Clippers

Back when the bands were full of AM signals, one had to punch through QRM to be heard. Low-level audio clipping kept the average modulation percentage high at the expense of good-sounding audio. Clippers produce distortion and audio harmonics, which are removed by a low-pass filter, usually cutting off at about 3 kHz. The gain stages following the clipper still must be of exceptional quality, otherwise baseline shifts from poor low-frequency response or phase distortion may nullify the benefits of clipping.

Transmitters such as the KW-1 include a splatter filter after the modulation transformer, cutting off at approximately 3 kHz, and include a clipper and low-pass filter as well. Most owners have now removed these items.

Clippers have no place in ham AM transmitters today. With suitable response shaping, the audio can have sufficient punch while still sounding clean. **ER**

Editor's Note: This is the first part of what will be a three part series. Part Two next month.

Reflections from page 2

Over the months and years ahead, that he wrote for ER, he was always genuine and interesting. I was told by someone who knew Fred well that he was very proud of his 'Reflections' column and was very happy doing it. As far as I know, this was the first writing for publication that Fred had ever done.

I never met Fred face to face. I regret this very much. If I had ever made a trip to California I would have made Nevada City one of my first stops. I've been told by other hams, who had visited Fred at his QTH in Nevada City, CA, that he lived alone and that he was totally devoted to vintage/AM radio.

Fred was one of the hams who stayed with AM through the lean years when SSB was taking over. He was also a devotee of CW, a carryover from his years at sea as a radioop.

There's not a whole lot more I can say about Fred other than he was a good friend and I miss him. **N6CSW/Ø**

The issues that Fred's 'Reflections' column appeared in are as follows: #1-#7; #9-#14; #16-#17; #19-#22; #24-##41. His last column was #44.

Good Audio

Part Two

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Compressors and Peak Limiters

Compressors are like AGC circuits: they act quickly on bursts of audio and release the attenuation slowly to keep the average audio level constant. Below a certain input level threshold, gain does not vary, but above the threshold, the compressor gain is reduced to keep the average output level constant.

Note that I said "average level". The speech waveform is complex, and although the compressor affects the average power level, peaks may still sneak through. The compressor gain reduction attack time is a few milliseconds, so low-frequency signals are not distorted. (The compressor gain change must be slower than the longest period of the signal.) The longer release time prevents the gain from rushing up between words and phrases, and reduces the room echo.

Some audio transients are bound to get through and overmodulate the transmitter. Often audio compressors are cascaded, with the attack/decay times of the front-end ones slower, followed by compressors with faster attack/decay times. Compressors operating with short time constants are sometimes called peak limiters.

At W6BM, a Gates Compander with a very long release time is followed by an Altec 436C with a 1.3 second decay time, followed by a CBS Volumax 400 peak limiter with a short attack/decay time to clean up the remaining fast transients.

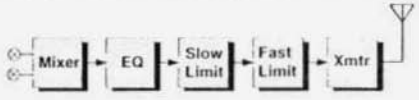

Fig. 4

Alternative Transmitter Audio Feedpoints

The output level of commercial audio processing equipment is usually 10 to 30 dBm, (dB above 1 milliwatt, or about 2.5 to 25 volts rms into 600 ohms). This is too high for the microphone input, as it will overload the stage before the audio gain control. An alternative is to feed the audio right across the modulator gain control, shunted by a 600 ohm resistor to correctly terminate the audio source. Once the limiter and modulator gain controls are properly set for 100% peak modulation, only the gain controls upstream of the limiters should be adjusted.

Distortion

Distortion significantly affects the audibility, or the ease of understanding the words. Clipping, overmodulation, saturated audio transformers and poorly biased modulator stages are the chief causes of distortion. All of these are curable.

The famous "Valiant Sound" is due primarily to saturation of the audio driver transformer by d.c. flowing through the primary, magnetizing the transformer core to near saturation. A modification has been published (Staples, ER #24) which cures the deficiencies of the original circuit.

The idle modulator current should be adjusted to the transmitter specification. If the tubes are weak, they may go into distortion before 100% modulation is reached.

Inverse feedback around the high-level stages following the gain control may help reduce distortion in the output stage.

Take care to eliminate r.f. from the audio circuits: they may rectify the signal and produce feedback. R.F. pickup in low-impedance circuits may be eliminated by placing a 0.005 microfarad capacitor from each side of the balanced line to ground at each piece of equipment.

Class AB2 modulators draw grid current during part of the cycle. The driver must have a low source impedance so the waveform is not distorted during grid current flow. The bias supply decoupling capacitor from the center tap of the driver transformer to ground must be in good condition to lower the impedance of the audio drive to the modulator tubes.

Other causes of distortion are insufficient grid drive, preventing full upward modulation, or weak (emission limited) final amplifier tubes, also preventing full upward modulation.

Monitoring

I am constantly amazed at how few stations have monitoring facilities. Monitors generally fall into three categories: level meters, oscilloscope displays and aural monitors (headphones).

Average level meters, such as VU indicators are the least effective. Mechanical meter movements respond slowly, missing the audio peaks that cause splatter.

Commercial AM modulation monitors, such as the popular General Radio 1931 (A,B) are making their appearance at ham flea markets. These monitors display peak modulation level and carrier shift. The peak level is indicated by a lamp, which can be set to flash at a preselected negative peak modulation level, up to 100%.

The carrier shift meter is useful in establishing the proper operating conditions of the final amplifier. The carrier shift meter indicates the average carrier voltage, which should stay constant during modulation. (The peak voltage for 100% sine-wave modulation doubles, and the average power output increases by 50%, but the carrier voltage, averaged over one period of the modulation waveform, remains constant). Downward carrier shift may indicate overmodulation or poor high-voltage regulation, and upward carrier shift may indicate parasitics. Tuning single-sideband transmitters may be facilitated by using a simple carrier shift metering circuit (Staples, ER#36).

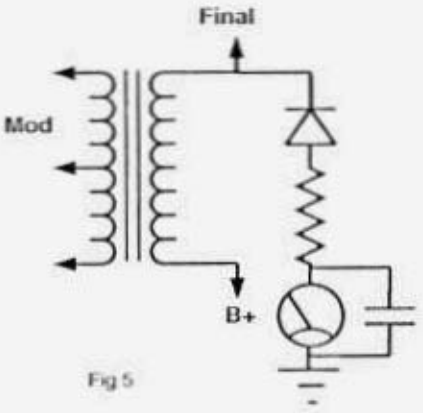

Fig 5

An effective negative-peak overmodulation monitor may be constructed by connecting the cathode of a high-voltage diode to the modulated B+ line to the final and the anode to ground through a meter. Upon negative swings of the modulated B+, the diode will conduct current and deflect the meter.

Oscilloscope-based modulation monitoring provides better information, with a trapezoidal-pattern display easier to interpret than an envelope display (Staples, ER#11). An envelope display is certainly effective, and will help set the phase of the audio to maximize the positive modulation peaks. If the negative peaks appear more prominent than the positive, try switching the audio phase as described above. Overmodulation appears as "beads" along the baseline. My own transmitter has a trapezoidal monitor built right into the final amplifier (Staples, ER#15).

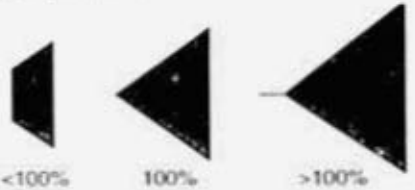

Fig 6

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Aural monitoring is perhaps the easiest, requiring a pair of headphones, a diode, a few feet of antenna and a few other small parts (Staples,ER#36). The modulation level can't be accurately monitored, but hum, noise and distortion can be heard. It is useful to be able to reverse the phase of the phones. If the headphone phase is improper, the whole bass register will be lost by destructive interference between the headphone audio and the bone conduction audio from the larynx to the ears.

High-Level Modulation Circuits

The modulator power output capability must be at least one-half the d.c. power input to the final r.f. amplifier. The d.c. power input to the modulator stage is almost equal to the input power to the final for 100% sine-wave modulation, as the plate efficiency of a class-B modulator output stage is usually around 60%. Full 100% sine-wave modulation stresses the modulator and high-voltage power supply.

Triode final amplifiers and pentodes with proper co-modulation of the screen grid voltage have a fairly linear voltage-current characteristic, so the final amplifier plate current approximately follows the instantaneous plate voltage. One modulator tube may work harder than the other due to the varying load impedance of the final amplifier. This may cause distortion due to asymmetrical loading on the positive and negative modulation peaks. Negative peak loading circuits, consisting of a resistor and a diode connected across the modulation transformer to absorb some of the power on the "easy" half of the cycle may reduce this possible source of distortion. A fixed resistor may be included in the plate lead of one of the modulator tubes to equalize the load (Kleronomos, ER#7).

The ultramodulation configuration allows more audio to be placed on the carrier by rectifying part of the audio and adding it to the final B+ voltage, which keeps the modulated B+ from swinging down through zero (Kleronomos, ER#3). This circuit increases the signal level, but at the expense of significant carrier shift and distortion. Since the 1.5 KW legal power limit now refers to peak envelope power, it makes no sense to employ this circuit. Any scheme that causes the average carrier level to fluctuate at a syllable rate, such as controlled-carrier schemes, should be avoided, as they play havoc with the AGC action of many receivers.

With the price of 810's increasing, alternative tubes may be used. Triode-connected 813's work well in transmitters of this power level, operating at almost zero bias. All three grids are connected together, and fixed bias may be derived from a zener diode in the cathode circuit. One advantage of zero-bias operation is that the driver is loaded over the entire audio cycle, not just at the peaks. Swamping resistors may be placed across the secondary of the driver transformer to stabilize the driver load if enough drive power is available.

A technique used in broadcast transmitter isolates the d.c. current flow from the secondary of the modulation trans-

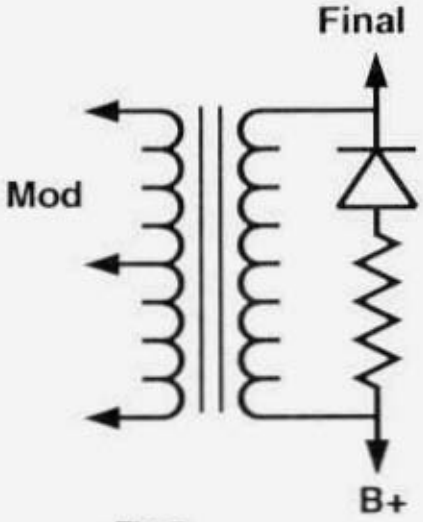

Fig 7

former by feeding plate voltage to the final amplifier through an audio choke which is coupled to the modulation transformer secondary through a d.c. blocking capacitor. This prevents magnetization of the transformer core, raising its inductance, and providing better low-frequency response at reduced distortion.

Almost all high-level modulated broadcast transmitters use push-pull audio amplifier stages throughout and employ negative audio feedback from the plates of the modulator tubes to the grids of the first stage to reduce distortion and stabilize the gain. Negative feedback can be used to advantage in ham transmitters, usually over the last two or three stages preceding the modulation transformer. This will require some experimentation to achieve stability, particularly during transients introduced by overmodulation. Circuit modifications incorporating negative feedback have been published for the Johnson Valiant (Staples, ER#34).

Protecting the Modulation Transformer

During overmodulation, the final plate voltage swings below zero, cutting off the final amplifier plate current. This effectively disconnects the load from the modulator resulting in an open circuit condition on the modulation transformer secondary. What happens next depends in part on the source impedance of the modulator itself.

If the modulator output stage uses triodes, which have a relatively low output impedance, (at least one is always conducting on audio peaks), enough damping may be present to prevent the voltage on the secondary of the modulation transformer from soaring. Pentode or beam power modulator tubes, on the other hand, operating without inverse feedback, provide no such damping and the voltage across the secondary may go high enough during negative overmodulation peaks to cause breakdown. A spark gap across the secondary of the modulation transformer adjusted to break down at a bit more than twice the d.c. supply voltage will protect the transformer (Dennison, ER#25).

Additional protection for the transformer is obtained by isolating the case from ground and allowing it to float up to high voltage potential, reducing the voltage stress between the windings and the iron core. Perhaps half of the modulation transformers in the KW-1 and the Johnson Desk Kilowatt transmitters have already failed (they use the same transformer). Make sure that the transformer is made inaccessible for safety.

Low-Level Modulation Circuits and Single-Sideband Transmitters

Some AM transmitters including many older broadcast transmitters generate the AM signal at low level and amplify it with linear amplifiers. The amplifiers must be capable of providing a peak power output of four times the unmodulated carrier power. The efficiency of class-B linears at the unmodulated carrier level is typically about 33%. To produce the legal limit of 1.5 KW peak envelope power, or 375 watts of unmodulated carrier at 33% efficiency, the unmodulated carrier input power would be 1136 watts, and 761 watts is dissipated as heat on the plates of the output tubes. A 1 KW carrier broadcast transmitter with a linear in the final dissipates 2 KW on the plates. Linears designed for sideband use do not react well to this kind of abuse.

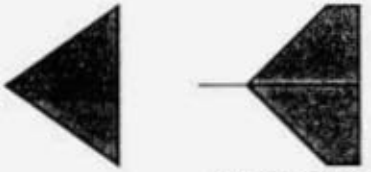

Fig 8

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perhaps the Navy's requirement included only very rare frequency changes so that no added complication was justified.

The technical manual is only fair; while everything you expect to find is there, the discussion is superficial on the harder subjects where you most need help. For example you can really understand how the Collins Autotune mechanism works by studying the ART-13 manual – but not Aircraft Radio's retuner from the ARC-39 manual.

The ARC-39 breaks no new technical ground. It does, however, make good use of the ideas of the 1950's and deserves special mention for the extensive use of parts designed for the 'command' sets. Aircraft Radio probably had stocks of some parts and tooling to produce the others; recycling them in a new design certainly saved some money. As one of the early examples of cost controlled design and as a set with many good features and only the most minor of faults, the ARC-39 deserves to stand among the first rank of U.S. military radios. **ER**

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The most common problem in operating sideband transmitters on AM is correctly setting the carrier and modulation level. If the carrier level is too high, there is no headroom for the positive modulation peaks, which are at four times the unmodulated carrier power level. As most of these transmitters are rated at 100 watts peak envelope power output on sideband, the AM carrier power rating will be 25 watts. The output meter on such transmitters may measure peak r.f. voltage, average voltage, or something in between. Averaging meters will not deflect at all during modulation, and so do not provide any indication of proper AM operation.

An oscilloscope is useful in setting the operating conditions correctly. When properly set, the oscilloscope will show sharply defined upward peaks about twice as high as the unmodulated carrier voltage, with the downward peaks just touching the axis. Any flattening of the upward peaks must be avoided, as the amplifier (or exciter) is going into saturation.

If the modulating audio signal is available for a monitor scope, a trapezoidal modulation display is useful for tuning a low-level AM-linear amplifier combination, with the audio signal providing the horizontal 'scope sweep. The amplifier is tuned and biased to straighten the sides of the trapezoid.

The audio processor on sideband rigs should be turned off, and the transmissions should be kept short, as AM operation imposes an undue strain on the power supply and output amplifier. Also, use push-to-talk instead of VOX on AM. **ER**

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nio; sons Ronald Bernard Koby of San Antonio and Ted Koby of Minnesota; brother Pierre Koby of San Bernadino, California; 12 grandchildren, 4 great-grandchildren; and numerous nieces and nephews."

Editor's Note:

Otis Nonken, K5SWK, was Koby's lifelong friend. Otis told me that they had worked each other for 35 years and had never had a dull QSO. To me they were a nightly 'instituition' on 3880. Their signals were always loud here in Colorado and it was always interesting to tune in on their QSO's.

Koby's passing has deeply affected Otis. In a recent letter he said, "God I wish I could go out to the shack and still hear his deep, deep, voiced modulation. I'd never complain again."

We will all miss Koby, K5MZH.

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Part Three

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Commercial Audio and Monitoring Gear

Used broadcast and audio production gear is making it to the surplus market and is readily adaptable to the ham shack. Mixer amplifiers, equalizers and compressors (limiters) may be obtained at reasonable cost. All this equipment operates at low impedance, with an audio level of typically 0 to 30 dBm (1 milliwatt to 1 watt) into a 600 ohm balanced load. You can't connect an unamplified high-impedance crystal microphone to the input of one of these low-impedance mike mixers.

Mixers typically provide several inputs, which can be configured for low-level, low-impedance microphones by using plug-in preamplifier modules, or for high-level sources by omitting the preamp. The amplified D-104 drives the high-level inputs on these mixers well, as well as most consumer audio sources.

The mixer may be followed by equalizers and limiter amplifers. The gain of the limiters is generally quite high, and they may be driven by audio sources operating down to perhaps -30 dBm, which includes the amplified D-104.

Off-the-air modulation monitors are available, such as the popular General Radio 1931 (A,B), the Western Electric 26W and the Gates M-5693. These units require about 1 watt of r.f. from the transmitter, which may be taken off the feedline through a small wide-space variable capacitor. These monitors indicate carrier shift during modulation, and average and peak modulation percentage. They have a 600-ohm audio monitor output which can drive headphones.

Tape Recorders

A cassette tape recorder is a useful addition to the station. I use one to play back the Ham Radio Newsline report after the Wednesday night AM swap and to play back air checks. I record roundtable participants with a wide selectivity setting, and the listener can verify the playback fidelity by comparing it with direct reception of the same signals. Nothing works as well, or as diplomatically, in pointing out audio problems than letting the offender hear himself, comparing his to the other signals in the roundtable.

(The Newsline program is recorded off the phone line through a transformer audio coupler with the phone in the mute mode, preventing room audio from being recorded. I use a monitor amplifier and speaker, switchable among many sources in the audio chain, including an off-the-air monitor, to check the recording and the playback. The mike mixer permits audio inserts for station identification during the Newsline playback.)

Broadcast Transmitters

Broadcast AM radio is in financial trouble, and stations are folding or unloading their old vacuum-tube transmitters in favor of no-maintance, efficient solid-state equipment. The old transmitters are being bought up by the ham community, and are fun to restore back to life, usually on 160 meters, but 75 meter operation is possible with many of these old transmitters.

The power efficiency of AM broadcast transmitters has increased remarkably over the years. Older transmitters usually ran about 20 to 25% efficiency, a.c. line input to r.f. output. Today's pulse-width-modulated solid-state transmitters are running up to 86% efficient, a remarkable improvement. Their excellent reli-

ability has been welcomed, as broadcasters are no longer able to keep maintenance personnel at the transmitter sites.

Commercial AM transmitters in the 250 to 1000-watt power range are significantly larger than ham transmitters of the same power rating. They can be remotely controlled and placed in the garage, but since they are also pretty to look at, many hams are accommodating them right in the shack (*QST*, February 1993).

These transmitters are crystal-controlled, but can be driven by small VFO-exciters such as the Johnson Navigator. Their external drive power requirement is usually more than can be delivered by standard outboard VFO units. The audio input level required is typically 10 milliwatts (10 dBm) into 600 ohms.

These transmitters use tubes familiar to hams: 4-250's, 4-400's, 810's or 813's. The 833-A was popular in the 1 kW transmitters. The rectifiers are usually 866-A's in the smaller units and 872's in the larger ones. The later vacuum-tube transmitters use higher gain pentodes or beam power tubes in all the r.f. and audio stages to reduce the number of stages.

Some of these transmitters require three-phase primary power, which reduces the rectifier and filter component sizes, but is a headache for the ham. The power transformer may need replacement and the ripple filter may need to be upgraded.

Some transmitters such as the Western Electrics, use low-level modulation and Doherty final amplifiers, which are more efficient than the usual linear amplifier, but are difficult to change frequency once they are tuned. Others, such as some of the RCA's, employ neutralization circuits that are frequency-sensitive. These transmitters might as well be kept crystal-controlled on one frequency. Other transmitters, such as Collins or Gates, use circuits more familiar to hams and are perhaps the easiest to convert to ham frequencies.

Receiving

The receiver plays an obvious role in determining audio signal quality. Each receiver seems to have its own "sound", some better than others. The receiver need not have a fancy push-pull audio output stage: some of the best receivers I've heard have a simple single-ended audio stage. The sound of a receiver depends on the front-end design, the i.f. bandwidth, the detector, and the audio amplifier design.

Poor receiver front ends are subject to overload and cross-modulation by nearby strong signals, which increase the noise background. An input attenuator may help, but most vacuum-tube receivers have quite good front-end characteristics. Phase noise in the h.f. oscillator in the old vacuum-tube receivers (which produces hissy sidebands) is almost always low, but it can be quite high in the early solid-state receivers, and is almost guaranteed to be so in early synthesized solid-state units. High local oscillator phase noise will heterodyne a wide spectrum of signals into the i.f. channel, producing unwelcome background noise.

The i.f. bandwidth characteristic is important in determining the sound of a receiver. A narrow i.f. strip chops off the sidebands and remove the highs. Mechanical filters, with their sharp skirts, produce a sharp audio cutoff, which is perceived as a ringing at that frequency. However, 15 kHz wide mechanical filters, if the peak-to-valley ripple amplitude is below 3-4 dB, can sound excellent, as the cutoff is beyond the transmitted audio spectrum, yet adjacent signal selectivity is still adequate.

The last i.f. stage of the Hammarlund SP-600 tends to overload on strong signals, but an easy modification cures that problem. Replace the last i.f. tube with a 6AH6, and connect a 10k resistor from the junction of R56 and R57 to ground to change the bias.

Selective (distortion) fading can be reduced by the use of a synchronous detector which also provides a low-distortion

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Good Audio from previous page
demodulation of the signal (Staples, ER#30,34). Frequently, just turning on the BFO and zero-beating the signal can help reduce selective fading distortion.

The frequency response of the audio system may be widened by increasing the value of the coupling and bypass capacitors and decreasing the value of the shunt capacitors, except that of the detector load capacitor. Negative feedback may be included around the last audio stages. The 75A-4, usually not considered a superior AM receiver, when provided with a 15 khz mechanical filter and an additional audio feedback circuit in addition to the two that already exist (W9FGJ, priv. comm.), is a fine sounding receiver.

Fig 9

Among the best sounding receivers I have heard are the AR-88, SX-73, R-390 and many of the middle-range receivers that have a fairly wide i.f. bandwidth. Receivers to avoid are those with low final i.f. frequencies and receivers with narrow mechanical filters. The HRO-50T and HRO-60's have a rather narrow i.f., which gives them a somewhat bassy sound, but their excellent skirt selectivity and gentler i.f. selectivity roll-off draws many fans.

A good speaker, not one of those little, inefficient so-called hi-fi bookshelf speakers, but a nice, big 10 or 12 inch speaker in a decent cabinet helps. Place the speaker up against the wall, or preferably in the corner, to develop the bass response. Squirt your volume controls with cleaner (or WD-40) to get rid of the scratchiness.

I keep a dozen or so receivers available for different conditions and moods at my primary operating position. I have provided each receiver with a standard connector carrying the antenna, speaker and break-in connections, so I can easily move receivers to other operating positions, or down to the basement shop for service. My station controller allows all these receivers to be selected by a rotary switch. Two speakers are available, selected by another switch on the station controller.

Improving Your Own Signal

So, what can you do to improve your audio? You can start by ensuring that your microphone is in good condition and by monitoring your own signal. Then, with a little bravery, you might try some modifications to the transmitter. You may later want to include external audio processing equipment so you can play broadcast station.

You can't go wrong with an amplified D-104 fitted with a new crystal element. The response of this mike is ideal for AM operation and, with a good transmitter, nothing more needs to be done. It has a natural sound without any obvious resonances or peaks, and the low-impedance output can drive any type of audio equipment. Some transmitters, such as the Collins 32V series, have a rather low-gain audio channel and benefit from the higher output. Others, such as the Johnson Ranger, have lots of gain and work well with an unamplified microphone, although the value of the first stage grid resistor may be increased to 2 or 3 megohms for a better sounding bottom end.

Used D-104's frequently have marginal crystal elements with low output or poor frequency response. New elements are available for $19 and are well worth the cost. I have not had any experience with ceramic replacement elements.

Build an audio monitor (Staples, ER#36). You can make one with a silicon diode, a pair of headphones and a couple of feet of antenna wire.

Talk a member of your roundtable into installing a tape playback facility so you can compare your audio to the others in the group. This is much better than vague aural reports, sometimes overdiplomatic, about your audio quality.

If you have a transmitter known to have deficient audio, such as the Johnson Valiant, modify it. The modified Valiant is one of the best-sounding rigs on the air. Some rigs can be improved by widening the audio frequency response, but if the driver and modulation transformers are inadequate, this may not result in the improvement you expected. The Collins rigs have good iron and a modified KW-1, less the clipper, low-pass filter and splatter choke, sounds excellent. Just as nice is the Johnson Desk Kilowatt with a Ranger as the driver.

Watch your modulation level carefully. A 'scope with a trapezoid presentation is the best, but an envelope display is also effective. Overmodulation seems to be more common than undermodulation, and is less obvious to the casual listener. Some rigs don't have enough audio power to fully modulate the rig, and a 'scope can point this out. You may have insufficient r.f. drive or weak tubes in the modulator or final.

R.F. feedback to the audio system or VFO can cause audio problems. Check your mike cable and connector for good ground to the transmitter, and if feedback persists, put a small r.f. bypass right before the first audio amplifier stage. R.F. feedback into the VFO compartment can cause unwanted frequency modulation of the signal. The VFO compartment of the Johnson Ranger/Valiant/500-family of transmitters occasionally loosens up, which can cause FM, particularly on 160 and 40 meters where the VFO operates straight through at the output frequency. Tighten the screws of the VFO compartment.

Experiment with an equalizer. It doesn't need to be fancy, but you will need an amplified microphone to drive it. Be sure that r.f. does not get into the equalizer, particularly if it's solid-state. Don't overdo it -- start with small changes and get opinions from the rest of your roundtable as you adjust it.

Summary

In this article, I've discussed issues affecting audio quality from the microphone to the loudspeaker. Good audio is not hi-fi audio: it is a low distortion audio with a frequency response optimized for ham-band AM communications.

We AM'ers are reviving an older operating mode with vintage equipment, but in a different operating environment, where talk power is less important now than a clean-sounding signal. These old transmitters can use some help in redefining their original communications intent. Feel free to experiment with this old equipment and make it exceed its original specifications. The rebirth of AM has attracted lots of new listeners, many of whom have become hams and joined us. Good audio is one of the natural attractions of AM operation, and I hope I have helped you improve the sound of your own station. **ER**

Biographical info:

Ham since 1956
Extra Class since 1958
Previous calls: K9CPZ, W6RGS, 7J1AFX
First Phone Commercial license since 1958
5 years BC experience, early 60's
PhD in nuclear physics
Active on 160 and 75 West Coast groups
Primary rig: homebrew 813
Contributed several ER articles
Collecting antiquarian radio equipment for 25 years

Editor's Note: Next month we'll print some of the letters we've received in response to John's article.